Optimizing buffer times and supplements in passenger robust timetabling

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We propose an innovative approach to build a timetable and routing plan from scratch for large and complex railway station areas. In railway planning for passengers, short and reliable passenger travel times are a must. Therefore, our objective is to directly optimize the passenger robustness, which means that the passenger travel time in practice in case of frequently occurring small delays, is minimized. There are three main indicators that influence the passenger robustness. The first indicator is *the capacity usage of switches* in the network. The more trains are planned to use a certain switch or platform, the more trains can be affected by a delay of one of the other trains that use that shared switch or platform. The second indicator is *the buffer time* between every pair of trains on a shared switch or platform. A train reserves (releases) an infrastructure element from the moment it passes the signal the closest before (after) that infrastructure element with the head (tail) of the train. The buffer time is the time between the release time of the first train and the reservation time of the second train on the shared infrastructure. The smaller the buffer time between two trains on the shared infrastructure, the higher the probability on delay propagation between these two trains. The third indicator are *the supplements* added to the minimum necessary running and dwell times of the trains. Without supplements, a train can never absorb its delays. Supplements are necessary to be able to catch up to the original schedule in case of a delay. Note that supplements increase the planned travel time of trains and passengers, while buffer times only affect the planned passenger travel times in case of transfers.

In practice, usually 5% up to 7% of the running and dwell times are added as a supplement. Since supplements increase the planned travel time and decrease the available capacity, our objective is to schedule these supplements with more care. The authors in [?] allocate running time supplements to a single train on a number of consecutive trips. As a result of the many interactions between trains in complex station areas this approach is not straightforwardly applicable for this input. The authors of [?] combine timetabling on the macroscopic and microscopic scale to compute a feasible, stable and robust timetable. While our approach makes the trade-off between supplements and buffer times on the microscopic scale, in their approach this trade-off is made during the macroscopic timetabling phase and they only evaluate it afterwards on the microscopic scale. The authors of [?] construct a timetable and make a platform assignment for the whole Belgian railway network. However, also here, the decision on the inclusion and the amount of supplements is made on the macroscopic level and only slightly adapted in case of infeasibilities on the microscopic level.

We set up an approach in which a routing model, a timetabling model and a simulation tool interact. The routing model constructs a routing that minimizes the capacity usage of the railway station area for a given line planning [?]. The routing model is extended to take capacity usage in terms of time into account in order to do an early check for infeasibilities. Subsequently, a timetabling model strives to maximize the buffer times between the trains, while constructing a conflict-free and realizable timetable. We extended the timetabling model proposed in [?] to take passenger numbers into account. Based on the output of the simulation tool of [?], we determine where, how large and for which trains it is useful to include supplements in the running and dwell times. This information is used as feedback for the routing and timetabling model to construct a better routing plan and timetable.

The main contribution of this work is an approach to construct a conflict-free and passenger robust routing plan and timetable for a large and complex railway station area in which the amount and placing of buffer times and supplements is carefully optimized. The approach is validated on Brussels' complex railway station area by using data from the Belgian railway infrastructure manager Infrabel. The passenger robustness can be improved with up to 17.6% compared to a reference timetable from Infrabel and up to 5.8% compared to a reference timetable from literature [?].

References

[1] Bešinović, N., Goverde, R.M.P., Quaglietta, E., Roberti, R., 2016. 'An integrated micro-macro approach to robust railway timetabling', *Transportation Research Part B: Methodological*, vol. 87, pp. 14–32.

[2] Burggraeve, S., Vansteenwegen, P., 2016. 'Robust routing and timetabling from scratch in complex railway stations', *Transportation Research Part B: Methodological*, under review.

[3] Dewilde, T., Sels, P., Cattrysse, D., Vansteenwegen, P., 2014. 'Improving the robustness in railway station areas', *European Journal of Operational Research*, vol. 235, pp. 276–286.

[4] Kroon, L.G., Dekker, R., Vromans, M.J.C.M., 2008. 'Cyclic Railway Timetabling: A Stochastic Optimization Approach', *Algorithmic Methods for Railway Optimization*, vol. 4359 of the series of Lecture Notes in Computer Science, pp. 41–66.

[5] Sels, P. and Dewilde, T. and Cattrysse, D. and Vansteenwegen, P., 2016. 'Reducing the passenger travel time in practice by the automated construction of a robust railway timetable', *Transportation Research Part B: Methodological*, vol. 84, pp. 124–156.